FUNCTIONAL BALANCE MEASUREMENTS IN BALLET DANCERS WITH VARYING VISUAL INPUT

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FUNCTIONAL BALANCE MEASUREMENTS IN BALLET DANCERS WITH VARYING VISUAL INPUT

Ballet dancers have been found to exhibit superior balance when compared to non-dancers. However, many believe this heightened balance is achieved by reliance on vision. Ballet dancers spend most of their time rehearsing in a studio with mirrors, providing consistent visual input. After a brief transition to the stage environment, which alters visual information, dancers perform in front of an audience.

The purpose of this study was to test if varying environmental factors diminished functional performance in ballet dancers. Healthy college-aged female dancers majoring in ballet performance in a Bachelor of Science program from a large Midwestern university volunteered to participate in this study. A repeated measures design was utilized. The independent variable was environment at three levels: studio facing the mirror, studio facing away from the mirror, and stage. The dependent variables were time in balance during a passé en relevé (seconds), 95% ellipse area (cm^2) during a double pirouette, and number of maximum fouetté rotations.

Change in environment elicited statistically significant changes in all dependent variables. Tukey post hoc testing revealed that performing on stage negatively impacted balance time, ellipse area and fouetté rotations. Time in balance during the passé en relevé decreased on the stage compared to both studio conditions (0.61 and 0.72 seconds). 95% Ellipse area during the double pirouette was larger on the stage compared to the studio without mirror (3.86 cm^2 larger). Number of fouetté rotations decreased on the stage compared to the studio with mirror (1.43 rotations fewer).

This study identified decreased balance and turning performance of ballet dancers on the stage in comparison to the studio. This may be due to the dramatic transition between studio and stage environments without allowing proper acclimation for ballet dancers to alter their performance or balance strategies with different visual input. It is important to recognize this deficit and to adapt training strategies to maximize performance abilities on stage. To do this,

increased training opportunities on the stage should be integrated into daily schedules and prior to performances.

MANUSCRIPT

(Prepared for submission to the Journal of Dance Medicine and Science)

INTRODUCTION

Ballet is an art form that requires exceptional balance abilities at all times.[1] Therefore, it comes as no surprise that dancers exhibit superior balance when compared to non-dancers.[2,3] The ability to balance utilizes information from the visual, vestibular, and somatosensory/proprioceptive systems.[4-7] In dancers, the reliance on visual information has been found to be the key element utilized for maintaining superior balance.[8,9] This reliance can be traced back to how dancers train.

Ballet dancers develop their skills by training and rehearsing in front of mirrors. This provides constant visual feedback, allowing them to incorporate visual cues from the mirror to correct their posture and to maintain their balance.[10] Dancers also learn to maintain proper vestibulocochlear equilibrium by "spotting."[11] During this technique, dancers fix their gaze at one specified area during rotational movements for as long as possible before quickly rotating the head around to refocus on the same spot.[12,13] Spotting allows dancers to limit excess head motion, maintain their controlled position, prevent dizziness, and allow the dancer to seamlessly transition to the next step.[11,12,14] Consequently, many believe the heightened balance noted in dancers is achieved primarily by reliance on visual cueing.[15-17]

Previously, this reliance on visual input has been studied in dancers predominantly by using an eyes-open versus eyes-closed approach during static balance testing in a laboratory setting. In this setting, it has been identified that a dancer's balance decreases with the removal of all visual information during eyes closed conditions.[16,18] However, the applicability of these findings to ballet performance is questionable, and no studies to date have directly investigated this question in a realistic performance setting.

As performance dates approach, rehearsals are often reoriented in the studio to face the back wall, removing visual cueing from the mirror. Next, dancers transition from the rehearsal

studio into the theater to begin a brief rehearsal period in the performance space, known commonly as technical rehearsal or "tech." This transition is dramatic as it removes all visual cues placing the dancer in an unfamiliar environment with bright lights (either from overhead, the side of the stage, or a spotlight), and a dark theater to gaze in to. This makes it more difficult for the dancer to select and return to an easily identifiable location for spotting, increasing the difficulty to maintain postural control.

Ballet dancers are expected to flawlessly complete choreography regardless of if they are in class, rehearsing for an upcoming ballet, or performing. These activities, however, occur in three diverse environmental settings and, currently, there is a void in the literature examining how balance might vary between these settings during functional ballet movements. It is important to understand how differences following environmental change and removal of standard visual cues impact performance. Objective data could highlight performance deficits this quick environmental change presents and allow for adjustments in training. Therefore, the purpose of this study is to test if varying environmental factors diminishes functional performance in ballet dancers.

METHODS

Subjects

Healthy, college-aged female dancers majoring in ballet performance in a Bachelor of Science program from a large Midwestern university volunteered to participate in this study. Participating dancers (n = 25) were 19.79 ± 1.44 years old, 164.49 ± 7.34 cm tall and weighed 56.64 ± 4.68 kg. Dancers participated in 24.38 ± 3.12 hours of ballet training per week, had 15.21 ± 2.11 years of total dance experience and 10.25 ± 3.03 years of formal ballet training. Subjects were excluded from participation if they currently had a lower extremity injury limiting or preventing their participation, had any vestibulocochlear dysfunction (such as vertigo or an

acute illness), or had lower extremity surgery within the last 6 months. Subjects read and signed an informed consent form approved by the University Institution Review Board for Protection of Human Subjects, which also approved the study.

Study Design

A repeated measures design was used to determine whether changes in varying environmental factors of visual input resulted in differences in each dancer's balance. The independent variable was environment at three levels: studio facing the mirror, studio facing away from the mirror, and stage. The dependent variables were time in balance during a passé en relevé (seconds), 95% ellipse (cm^2) during a double pirouette, and number of maximum fouetté rotations.

Procedures

All dancers completed testing in all three environmental conditions over three days. Tasks and conditions were counterbalanced for each dancer. Studio data were collected in the same ballet studio for both studio conditions. During trials with the mirror, dancers completed testing in the center of the studio on Marley dance flooring facing the mirror. During trials without the mirror, dancers completed testing in the same location of the studio on Marley dance flooring facing the back, non-mirrored wall. All testing was completed in ballet flats. This decision was made to control for the variability in pointe shoes as well as accommodate for the limitations of the instrumentation software.

Stage data collection was conducted on the university's main ballet performance stage. This stage is utilized for performances and is in high demand during all aspects of the year. This scheduling conflict resulted in constraints when capturing the stage condition data. Therefore, all dancers were tested in the stage condition early in the morning on one day. Testing was completed on non-sprung Marley dance flooring facing the audience under performance lighting

conditions. This included a dark house, 2 lights per side on booms as a low side light (referred to as kickers or shins), overhead front lighting at 45-degree and 75-degree angles, and a standard central spotting light.

Dancers completed the following activities: passé en relevé balance on their dominant limb, double pirouette en dehors, and maximum number of fouetté turns. Prior to testing, subjects completed a questionnaire and performed a self-directed ten-minute warm-up. Information collected as part of the questionnaire included age, height, weight, dance training history, preferred stabilization leg, and injury history to assess inclusion/exclusion criteria.

Passé en relevé balance

A plantar pressure mat by Tekscan (HR Mat Pressure Measurement System VersaTak Cuff Based, Boston, MA) was utilized to measure postural sway via center of force. The software used for this study was HR Mat Version 6.6. Detection of sensels activation and force application was captured to calculate the center of force. This information was used to determine the dancer's postural sway. The pressure mat was calibrated according to the manufacturer's directions for each dancer.

Dancers stepped onto the plantar pressure mat and took their natural first position with arms in first position. When instructed, dancers completed a relevé on their preferred stabilization leg, passé with their other leg, and attempted to balance for as long as possible (Figure 1). The stabilization leg was determined based upon which leg the dancer felt most secure balancing on. This preference was determined by the questionnaire and held the same across variables to maintain consistency between testing environments. Dancers were instructed to balance and to spot in the manner they would normally utilize during a standard ballet performance. Three test trials were completed following a practice trial. Balance time en relevé for each trial was calculated and the mean of the three trials was used for statistical analysis.

Double pirouette en dehors

Dancers took their fourth position with their stabilization foot on the plantar pressure mat to prepare for a double pirouette en dehors to their preferred turning side. When instructed, dancers completed the double pirouette and landed in fourth position (Figure 2). Dancers were told to move their arms from third to first to third position during the pirouette and spot as they normally would during a standard ballet performance. Three test trials were completed following a practice trial. Center of pressure information was captured, the 95% ellipse area (cm^2) was calculated for each double pirouette trial and the mean of the three trials for each condition was used for statistical analysis.

Maximum fouetté rotations

This task was performed on Marley dance flooring. Dancers took their fourth position on the floor with their stabilization foot located within a three-by-three-foot area marked by 1-inch gaffer tape. The dancer was instructed to begin with a single pirouette followed by their maximum number of fouetté turns en dehors to their preferred turning side and to land in fourth position (Figure 3). They were told to move their arms from third to first to second to third position during the fouetté and to spot as they normally would during a standard ballet performance. Three test trials were completed following a practice trial. Maximum revolutions were counted during each trial. A trial was completed when the dancer landed in fourth or if the dancer moved out of the area while turning. The mean of the three trials was used for statistical analysis.

Data Processing

Center of force data was collected via the computerized Tekscan software for the passé en relevé and double pirouette trials. These data files were then analyzed via a custom MATLAB script (The MathWorks, Inc., Natick; MA).

Statistical Analysis

Four dancers were excluded from only the double pirouette data processing due to failing all trials in at least one condition. Failed trials were identified if the dancer was unable to complete two full rotations, hopped between rotations, or moved off the mat while turning. Therefore, twenty-five dancers' data were used for fouetté and time en relevé statistical analysis and twenty-one dancers' data were used for double pirouette statistical analysis.

SPSS (version 25.0; IBM Corp, Armonk; NY) was used to perform statistical analyses. Three separate Repeated Measures Analysis of Variance (RMANOVA) were conducted for each dependent variable: 95% ellipse, balance time en relevé, and number of revolutions. Each RMANOVA had one within-subject's variable at three levels: studio facing the mirror, studio facing away from the mirror, and on stage. A priori alpha level was set at $p < .05$. Any significant differences were further analyzed with Tukey post hoc testing.

RESULTS

Passé en Relevé

Change in environment elicited statistically significant changes in balance time en relevé performance, $F(2,48) = 15.52$, $p < .001$, partial $\omega^2 = .39$, observed power = .99. Tukey post hoc testing revealed that varying environmental factors significantly impacted balance time between both studio conditions and the stage condition (Figure 4). Dancers performed worse in the stage condition compared to both studio conditions (Table 1). Mean differences between performance in the studio with mirror to stage was 0.61 seconds ((95% CI, .26 to .96 seconds), $p < .001$), and the mean difference in performance between studio without mirror to stage was 0.72 seconds [95% CI, .30 to 1.15 seconds], $p < .001$.

Double Pirouette

Change in environment elicited statistically significant changes in 95% ellipse area, $F(2,40) = 3.44$, $p = .042$, partial $\omega^2 = .15$, and observed power = .61. Tukey post hoc analysis revealed that varying environmental factors significantly impacted ellipse area between studio without mirror to stage (Figure 5). Dancers performed better in the studio without mirror condition compared to the stage condition (Table 1). Mean differences between studio without mirror to stage was 3.86 cm^2 [95% CI, .78 to 8.49 cm^2], $p = .12$.

Fouetté

Change in environment elicited statistically significant changes in fouetté performance, $F(2,48) = 4.29$, $p = .02$, partial $\omega^2 = .15$, observed power = .72. Tukey post hoc testing revealed that varying environmental factors significantly impacted fouetté rotations (Figure 6). Dancers completed significantly fewer fouetté rotations in the stage condition compared to the studio with the mirror (Table 1). Mean differences between studio with mirror to stage was 1.43 rotations [95% CI, .10 to 2.75 rotations], $p=.03$.

DISCUSSION

The primary purpose of this study was to test if varying environmental factors of visual input (mirrors and lights) diminishes functional performance in ballet dancers. After extensive rehearsal in a studio, there is a complete environmental change to a dark theater where the dancer has to perform under stage lights without the immediate feedback of a mirror. After only a few short days in this new environment, the dancers perform in front of an audience and are expected to execute choreography to the same caliber that was rehearsed in the studio. This study found that dancers exhibited decreased balance performance on the stage as compared to the studio.

Postural sway and ballet performance were objectively quantified by analyzing time in balance during passé en relevé, 95% ellipse during a double pirouette, and number of fouetté rotations. Decreased postural sway and increased performance abilities would have reflected a

longer time in balance, a smaller area of center of pressure during the pirouette rotations, and an increased number of fouetté rotations. Contrarily, we found a decreased ability to maintain balance on the stage in comparison to both studio conditions, decreased fouetté rotations on the stage in comparison to the studio with mirror condition, and a larger center of pressure area during double pirouettes on stage when compared to the studio without mirror.

Time in balance was chosen as the variable for the passé en relevé task because dancers typically strive for increased time in balance to exhibit control of their movement. The 95% confidence ellipse circumscribes an area of center of pressure in which 95% of the data points lie.[11] Due to the rotatory nature of the task, we believed area of center of pressure was the most appropriate variable to utilize. To successfully complete rotations, a dancer must stay within a small center of pressure. Therefore, a smaller area correlates to increased balance. An increased number of turns is also desirable by both the dancers and the audience; an increased number is perceived as having better performance qualities, which is why we used number of rotations as the fouetté turn variable. Turning ability can also vary greatly between dancers, producing greater capacity to discern between balance abilities and changes between environmental conditions.

Despite dancers attaining numerous hours of rehearsal prior to a performance, the majority of time is spent in the studio, allowing consistent visual input such as mirrors for adjusting technique and easily identifiable locations for "spotting." Many choreographers, teachers, and répétiteurs try to replicate the decreased visual input that occurs on the stage and prepare dancers for this transition by rehearsing pieces with the dancers facing the back of the studio as performances approach. This removes the feedback that would otherwise be gained from the studio mirrors. However, this still does not alter visual input as drastically as a stage condition. Even though the studio without mirror condition eliminated visual feedback from the

mirror, dancers could still easily identify locations on the wall to focus and return their gaze to during spotting. When on stage, dancers are in a much larger space so it is more difficult to identify and re-identify locations for spotting and their visual cues are now much farther away. Additionally, stage lighting during performances impacts visual input as bright lights are used to illuminate the stage and the dancers and the house is blacked-out.

Both studio conditions provide readily available visual information but each has its advantages and disadvantages. While the studio with mirror condition offers consistent visual feedback, the mirror may also allow for distraction as dancers can focus on other aspects of their performance as well rather than just focusing on one location for spotting. However, during the studio without mirror condition dancers are forced to strictly focus their gaze during spotting. This distinction may be able to explain the statistically significant difference found between studio without mirror to stage conditions during double pirouette performance.

Visual Input

Most of the previous literature regarding balance in ballet dancers has failed to incorporate realistic changes in visual information. When examining the sensorimotor system's contribution to dance, vision has been shown to be the dominant system in dancers.[15-17] This may be influenced by how dancers are trained. Dancers spend most of their time learning technique or choreography in the studio, which is typically surrounded by mirrors. While this offers immediate feedback to correct position[10], dancers may learn to use visual landmarks on their body seen in the mirror to fix their posture and therefore obtain increased postural control, rather than to rely on strict proprioception such as spotting during rotational movements.[11]

Choosing an identifiable location to focus on is integral for maintaining balance during a turn and is much easier when using a mirror. The consistent use of visual feedback during

training can cause dancers to become too reliant on mirrors and, in turn, require constant visual feedback to perform difficult ballet movements that require significant balance.[1,8,16,19-22] It has been found that dancers may become less dependent on this visual information with increased experience, but it still plays a vital role in all levels of dance.[8,18-22]

This study identified deficits in performance when on stage as compared to the studio conditions. Dancers could not balance as long in a passé en relevé, completed fewer fouetté rotations, and displayed a larger deviation in center of pressure during the double pirouette when on stage in comparison to the studio condition. Each of these factors correspond to inferior performance abilities in the stage condition. These deficits may be the consequence of an inability to utilize trained visual cues from quickly altering visual information without adequate time for adaptation.

Clinical Recommendations

Due to the pressures placed on ballet dancers to perform at their best while on stage, it is important to support this pressure with proper acclimation to the stage. Currently, most ballet students are given about one week on stage prior to a performance, known as "tech week," to prepare for performing in front of an audience. This short time integrates all performance elements, which may include costuming, lights, and live music, so there are multiple adaptations to preparation while the dancers strive to change their balancing strategies due to altered visual input. In order to allow adequate alterations in performance strategies prior to additional performance elements, dancers should be given more opportunities to train on stage. Options for this could include integrating technique classes and rehearsals on stage into weekly training schedules or allowing more time on stage than about one week prior to a performance.

Additionally, performance elements could be integrated into rehearsal studios. Instead of just having dancers face the back wall of the studio to remove visual input from the mirror, further steps could be used to integrate performance lighting in the studio. For example, black curtains could be used to cover the mirror, to mimic a dark house, while artificial anterior overhead stage lighting could be incorporated in studios to simulate performance lighting.

The clinical meaningfulness of our results are robust. While on stage, dancers completed 1.43 fewer fouetté rotations, balanced for .61 to .72 seconds less in passé en relevé, and used an additional 3.86 cm^2 for a double pirouette when compared to the studio conditions. In ballet, increased balance times and turning ability, as well as decreased area of center of pressure during turning, results in a performance that is extremely desirable and visually appealing for the audience. Although the mean differences found in this study may seem small, they correspond to large deficits in performance and may severely diminish an audience's perception of a performance.

Limitations

A possible limitation to this study was from an altered testing surface. The passé en relevé and double pirouette were completed on the plantar pressure mat surface, different than the sprung Marley flooring the dancers are used to, which may have altered typical performance.

Due to time and space constraints of utilizing the shared university stage, there was variation in days and times between testing sessions. However, all stage data collection was completed prior to technical rehearsals on stage, preventing acclimation to the stage. Times between studio testing conditions remained relatively consistent but the number of days between sessions did vary based on dancer availability. However, external factors such as prior physical activity, nutrition, hydration, sleep, caffeine intake, alcohol use, emotional and physical stresses

that may have altered performance were asked about prior to each testing session to ensure there were no substantial differences between testing dates.

For the passé en relevé, dancers started with feet in first position rather than in fifth position. This resulted in greater variation in center of pressure and may have caused the decrease in balance times for this task. Starting from first position is also not typically how dancers would enter this balance during a performance.

Finally, following testing, dancers expressed they may have performed better if given a full technique class beforehand rather than having completed a self-directed 10-minute warm-up.

Future Research

This study was the first to test the impact of varying visual cues on ballet performance using functional tasks in both studio and stage environments. The transition from studio to stage is a part of every performance that ballet dancers experience and is an important factor that future research should incorporate into realistic evaluations of balance performance. To make continuing research surrounding this relationship more realistic to performances, additional performance elements such as costuming and music cues could be included as well. Males could also be tested using pirouette a la seconde turns, as they do not typically perform fouetté turns, to determine if there are differences between sexes. Another realistic relationship that could be explored might be examining performance elements on the stage between dancers that use the traditional transition to the stage of only having about one week of acclimation prior to performances in comparison to dancers that have frequent acclimation on the stage in addition to prior to performances.

Conclusion

The primary purpose of this study was to test if varying environmental factors of visual input (mirrors and lights) diminishes functional performance in ballet dancers. This study

identified decreased balance and turning performance of ballet dancers on the stage in comparison to studio with and without mirror conditions based upon decreased balance time in passé en relevé, decrease fouetté rotations, and increased 95% ellipse area during a double pirouette.

Ballet dancers are expected to perform at their best when on stage in front of an audience but exhibited decreased balance performance when on stage. This may be due to the dramatic transition between studio and stage environments without allowing proper acclimation and alterance of performance and balance strategies to accommodate different visual input. It is important to recognize this deficit to performance and to adapt training strategies to maximize performance abilities on stage. To do this, increased training opportunities on the stage should be integrated into daily schedules and prior to performances.

TABLE AND FIGURE LEGENDS

Table 1: Means, Standard Deviations and Confidence Intervals for each ballet task in each environmental condition. The breakdown of mean, standard deviation and confidence interval results for each ballet task per environmental condition. Specified symbols denote statistical significance within each task.

Figure 1: Passé en Relevé. Image depicting proper form during a passé en relevé.

Figure 2: Double Pirouette. Image depicting proper form during a double pirouette.

Figure 3: Fouetté. Image depicting proper form during a fouetté turn.

Figure 4: Passé en Relevé Results. Figure depicting results of passé en relevé in all environmental conditions. Brackets denote statistical significance within each task. Error bars denote standard deviation.

Figure 5: Double Pirouette Results. Figure depicting results of double pirouette in all environmental conditions. Brackets denote statistical significance within each task. Error bars denote standard deviation.

Figure 6: Fouetté Results. Figure depicting results of fouetté rotations in all environmental conditions. Brackets denote statistical significance within each task. Error bars denote standard deviation.

TABLES

Table 1: Means, Standard Deviations and 95% Confidence Interval for each ballet task in each environmental condition

	Studio with Mirror	Studio without Mirror	Stage
Passé en Relevé (seconds)	2.38 ± .80* [95% CI, 2.05 to 2.71]	2.49 ± .92$^{\Delta}$ [95% CI, 2.11 to 2.87]	1.77 ± .43*$^{\Delta}$ [95% CI, 1.59 to 1.94]
Double Pirouette (cm^2)	10.24 ± 6.45 [95% CI, 7.30 to 13.18]	8.78 ± 6.20 $^{\Omega}$ [95% CI, 5.96 to 11.60]	12.64 ± 8.42$^{\Omega}$ [95% CI, 8.81 to 16.47]
Fouetté Rotations (number)	7.49 ± 2.23$^{\infty}$ [95% CI, 6.58 to 8.41]	6.72 ± 2.50 [95% CI, 5.69 to 7.75]	6.07 ± 2.73$^{\infty}$ [95% CI, 4.94 to 7.20]

*Identifies a significant difference between studio with mirror and stage conditions during the passé en relevé.
$^{\Delta}$Identifies a significant difference between studio without mirror and stage conditions during the passé en relevé.
$^{\Omega}$ Identifies a significant difference between studio without mirror and stage conditions during the double pirouette.
$^{\infty}$Identifies a significant difference between studio with mirror and stage conditions during the fouetté rotations.

FIGURES

Figure 1: Passé en Relevé

Figure 2: Double Pirouette

Figure 3: Fouetté

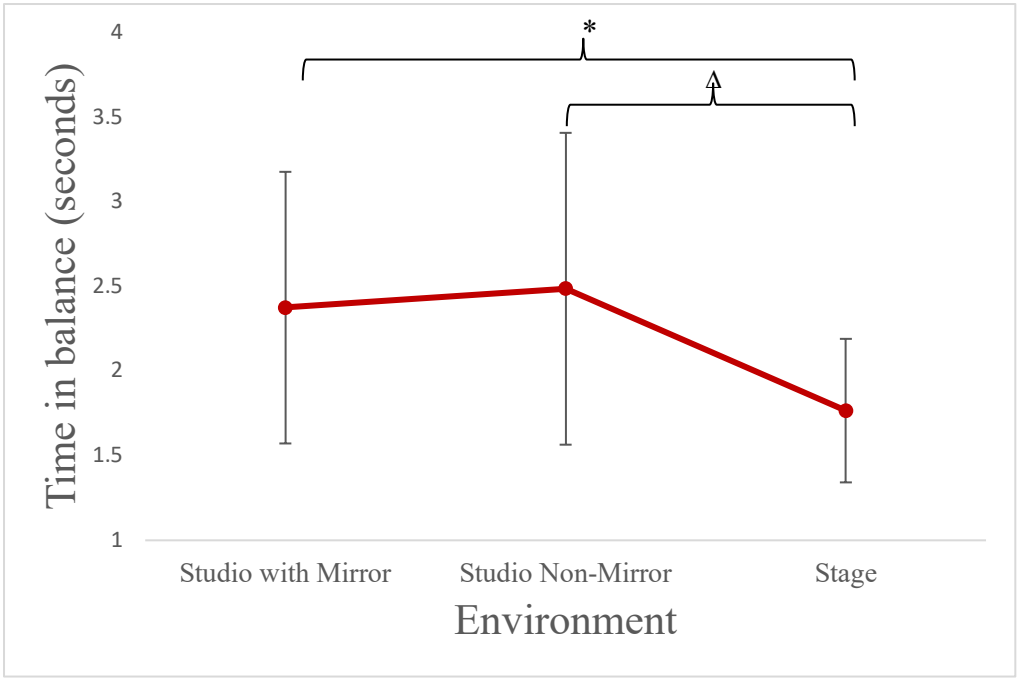

Figure 4: Passé en Relevé Results
*Identifies a significant difference between studio with mirror and stage conditions during the passé en relevé.
ΔIdentifies a significant difference between studio without mirror and stage conditions during the passé en relevé.

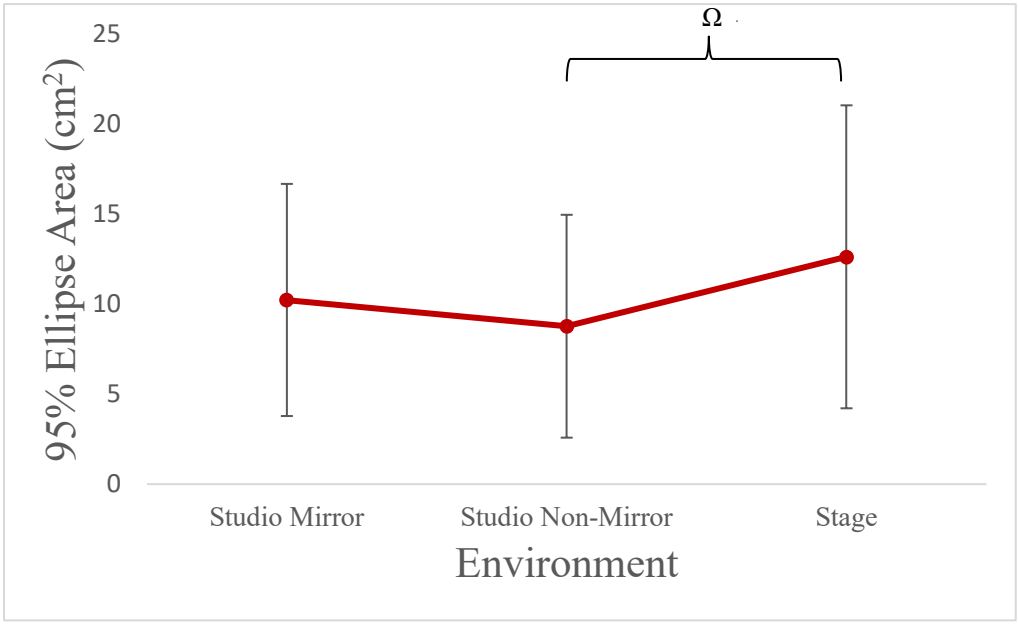

Figure 5: Double Pirouette Results
Ω Identifies a significant difference between studio without mirror and stage conditions during the double pirouette.

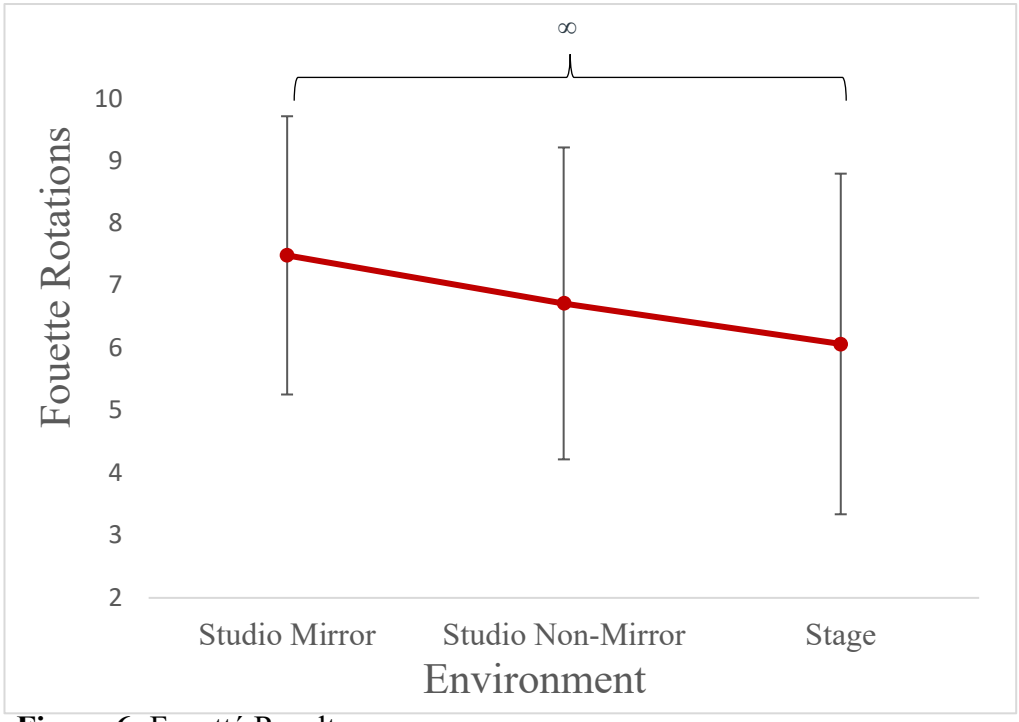

Figure 6: Fouetté Results

[∞]Identifies a significant difference between studio with mirror and stage conditions during the fouetté rotations.

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APPENDICES

APPENDIX A

Operational Definitions, Assumptions, Delimitations, Limitations, Specific Aims and Hypothesis, Variables

OPERATIONAL DEFINITIONS

- Ballet dancers: College-aged dancers that are part of a Midwestern collegiate ballet program whom have been training in classical ballet for at least 10 years.
- Balance: Objectified by plantar pressure mats to measure changes in the dancer's center of pressure during functional movements. A greater sway in the dancer's center of pressure suggests less stable balance.

- Plantar Pressure Mat: A portable, 5mm thick mat that can be placed on any surface consisting of 2288 sensors, spaced at 4 sensels/cm^2 or 25 sensels/in^2, collecting data at a speed of 40 Hertz. The mat is connected to a computer which collects and analyzes the center of force data.
- Center of force: This data will be defined according to the Tekscan Pressure Mat software and will be used to determine the subject's postural sway. For this study, center of pressure and center of force can be used interchangeably as the location of the area where the peak pressure of the body is positioned through the metatarsal heads of the feet.
- Anterior-posterior sway: The variation in center of pressure in the anterior to posterior direction. This will be measured in cm.
- Medial-lateral sway: The variation in center of pressure in the medial to lateral direction. This will be measured in cm.
- Center of force trajectory: The total path of the center of pressure. This will be measured in cm.
- Contact area: The area in which the center of pressure travels. This will be measured in cm^2.

- Performance: A ballet or any presentation of choreography executed by the dancers in front of an audience using performance elements such as lighting, costuming, and stage makeup. An example of this includes *The Nutcracker*.
- Functional performance: Ability of the dancers to maintain a stable center of pressure during functional movements to result in proper balance for a successful performance.

- Functional movements: Dance specific movements that are typically used during technique classes and incorporated into performances. Each movement has a ballet specific name as identified below.
    - Pirouettes: full body rotations completed on the stabilizing leg. For this study, dancers will begin and end in fourth position and complete the rotations turned out with the knee facing to the side of the body.
    - En dedans: inside turns where the working leg moves counterclockwise relative to the starting position
    - En dehors: outside turns where the working leg moves clockwise relative to the starting position
    - First position: A ballet position in which the dancer stands in turnout with heels touching or very close to each other. The arms will be held in front of the dancer in the shape of an oval at the naval level with a small space left between fingertips.
    - Second position: Arms in this position will be held straight out to the side with a slight bend in the elbow.
    - Third position: Arms in this position will be held with one arm in first position while the other is held out in second position. For this study, the arm in front will be opposite of the leg in front during fourth position.
    - Fourth position: A ballet position in which the dancer stands with the supporting leg slightly bent in front and the opposite leg straight back with both feet turned out. For this study, dancers will prepare for and land the pirouettes in fourth position.
    - Fifth position: A ballet position in which the dancers stand with the medial arch of the posterior leg meeting the lateral arch of the anterior leg.

- Glissade: starting in fifth position in demi plie, the anterior foot points out, both legs straighten in the air, and weight is shifted to the lead pointed foot followed by the other leg
- Relevé: Raising up onto and balancing on the metatarsal heads. This is completed by lifting the heels off the floor until the ankle is positioned over the metatarsal heads in maximal plantarflexion, mimicking a calf-raise.
- En pointe: balancing on the toe box of pointe shoes
- Visual input: Information provided from the mirrors in the studio which allow dancers to correct their positioning. For this study's purpose, this input will be compared to the lack of information while in the theater due to no mirror, bright stage lights, and a dark theater.
- Environmental Terms
    - House: The seats in a theater where the audience sits.
    - Marley: Non-stick flooring used by dancers for safety and shock absorption.
    - Studio: The space in which dancers take technique classes and rehearse choreography for performances. These spaces typically have marley flooring and are surrounded by mirrors for multiple viewing angles. Many studios include sprung-floors that are utilized in order to increase shock absorption and dampen the forces transmitted to the dancer's body.
    - Theater: The performance space that includes the stage, house, and backstage.
    - Sprung floor: Utilized for dancers' safety to absorb shock.
    - Barre: A long, horizontal wooden bar attached to the surroundings of the studio parallel to the floor. Provides an avenue for the dancer to increase stability while balancing by placing their hands on the barre.

- Flats: Ballet shoes resembling slippers with elastic straps to secure the shoe to the foot. Utilized primarily in the technique class setting by female dancers, and utilized as the primary shoe for male dancers.
- Pointe shoes: Ballet shoes that include a toe box to allow the female (almost exclusively) dancers to balance "en pointe" on the tips of their toes.

ASSUMPTIONS

- All dancers will have similar understanding and experience of ballet movements.
- Dancers will give full effort.
- Dancers will fully understand the instructions.
- Movements performed during testing will be similar in nature to those performed during standard dance activities
- Dancers will not have classes or rehearsals on the same day of testing
- Plantar Pressure Mat will provide reliable and accurate data

DELIMITATIONS

- Dancers will have studied dance for at least 10 years
- Dancers will be enrolled and participate in at least 5 days of ballet training per week
- Collegiate ballet dancers between the ages of 18 to 23 years old
- Dancers will not by physically limited at the time of testing and are allowed full participation in classes and rehearsals without modifications.
- Dancers will not have had surgery within the last 6 months
- Dancers will not have had an acute lower extremity injury within the last 3 months diagnosed by an Athletic Trainer or Medical Doctor
- Dancers will not be currently experiencing vestibulocochlear dysfunctions, such as vertigo.

- Dancers will wear their personal ballet flats for testing.
- Dancers will undergo two days of testing in studio and stage conditions.
    - Testing in the studio condition will consist of two testing sessions: facing the mirror and facing away from the mirror
    - Testing on the stage will consist of one testing session that mimics performance conditions using a dark auditorium and stage lights
    - Each testing session will take approximately 10 minutes and will include functional tests: passé en relevé balance, a double pirouette en dehors, and maximum fouette turns.

LIMITATIONS

- The participant pool will consist of only females due to the larger female population of the ballet program.
- Only college aged participants will be tested.
- Time and space constraints due to other uses of the performance space
    - Fatigue from performance due to timing of testing when the stage is available
    - Dancers may be psychologically stressed or fatigued due to the timing of testing
    - Dancers will be performing additional screening activities surrounding protocol which may cause fatigue
- The surface of plantar pressure mats is different than the sprung Marley flooring they are used to.
- Flooring of the stage will not be as sprung as the studio flooring.
- Other performance conditions such as the presence of an audience, music, and costumes will not be included.

- Dancers may be impacted by the psychological element of being in the performance space.
- Dancers will complete testing in ballet flats, not pointe shoes.
- Self-directed warm up (not a ballet class)
- Stage day all one day (time constraints) studio days spread out
- Had to manually cut the data
- couldn't balance for long enough to take all COP variables

SPECIFIC AIMS AND HYPOTHESIS

Specific Aim 1: To examine the change in a dancer's center of pressures during functional ballet movements when performed in a studio versus on a stage.

Hypothesis 1 H_A*:* There will be a significant difference in dancers' postural sway in the studio facing towards the mirror as compared to in the studio facing away from the mirror.

Hypothesis 2 H_A*:* There will be a significant difference in dancers' postural sway in the studio facing towards the mirror as compared to on the stage.

Hypothesis 3 H_A*:* There will be a significant difference in dancers' postural sway in the studio facing away from the mirror as compared to on the stage.

Hypothesis H_O*:* There will be no significant difference in dancers' postural sway on the stage as compared to in the studio.

VARIABLES

<u>Independent variables</u>

- Environment, at three levels:
    1. Studio facing the mirror
    2. Studio facing away from the mirror

3. Stage

<u>Dependent variables</u>

- Postural sway
    - Center of Pressure (center of force)
        - Passé en relevé balance
            - Time in balance (seconds)
        - Double pirouette en dehors
            - 95% ellipse (cm^2)
    - Maximum fouetté rotations (number)

APPENDIX B

Review of Literature

REVIEW OF LITERATURE

Injury Epidemiology

Due to the continuous, intense physical demand required by ballet dancers, overuse injures tend to be the most prevalent type of injury in this population.[1] Most ballet students have been found to incur multiple injuries during their career. However, dancers typically train through their injuries which may predispose them to recurrent injury.[1,2]

The most common areas affected by injury in ballet dancers are the lower extremity (foot, toes, hip, ankle, and knee), head, spine, and trunk, and include diagnoses of tendonitis, sprains, strains, and other overuse injuries.[1] When examining ankle instability, it was determined that subjects rely more on visual input for balance after sustaining an injury. This suggests that diminished proprioception due to previous injury may be a risk factor for future dance injuries.[3]

The ankle has the highest injury rate according to Negus et al[4] and Nilson et al[5]; specifically, ankle sprains have been reported as the most commonly reported ankle injury in ballet.[6] Injury rates in male and female dancers vary between 0.8-2.9[1] to 4.7 per 1,000 hours (self-reported data),[7] and 4.4 injuries per 1,000 hours in professional ballet dancers in the United States[1] with re-injury rates of 14% to 43.7% in pre-professional ballet dancers.[1,2] By comparison, high school gymnasts, swimmers, divers, football players, and soccer players have injury reports of 0.5-5.3 injuries, 0.2 injuries, 4.5 injuries, and 2.42 injuries per 1,000 hours of training respectively.[1,8] This demonstrates that even though ballet is a non-contact activity, it still presents with a significant risk of injury.[1] Other contributing factors to ballet injuries found in the literature, along with previous injury as mentioned above, were setting (i.e. environment) and fatigue.

Setting

The setting where the highest number of dance injuries take place has been shown to be technique classes. However, dancers have an elevated risk for injury during rehearsal, which may be due to fatigue from longer periods of activity.[9,10] Injuries that occurred during performances were typically due to slipping from irregularities on the surface from dirt, props, costumes, or getting stuck on uneven flooring.[1]

Fatigue Contribution

It has been found that injuries are more common late in the day or during performance season, especially when rehearsing known choreography. Rehearsing familiar work causes both neuromuscular and psychodynamic fatigue due to the repetitive movements, making the joints in the lower extremity more susceptible to injury.[10] When fatigue is present, multiple factors are inhibited or changed in the lower extremity, including: an increase in multi-directional

movement of the knee; a decreased muscular contribution with a shift to reliability on static stabilizers; decreased joint stability; and an overall decrease in balance control to further increase risk of injury.[10] However, a study by Hopper[11] and associates assessed the soleus during prolonged activity and determined that dancers with increased experience are more fatigue resistant, allowing proper maintenance of postural control throughout the entirety of their performance demands.

Psychological Factors

Another factor that may contribute to the high injury prevalence seen in ballet may be attributed to psychological factors impeding performance. As a dancer, choreography is taught and rehearsed in a studio for days, weeks, or even months at a time. During these rehearsals, the dancer receives constant feedback both visually from what is seen in the mirror and verbally from the instructor. Constant visual feedback from the mirror allows dancers to further understand the choreography and quickly correct their posture or the movement.[12-14] This can be extremely helpful and allows dancers to perceive themselves how others may view their performance.[15] After extensive rehearsal in a studio, there is a complete environmental change when dancers begin to work on the performance stage, under lights, possibly on a different surface, without the immediate feedback of a mirror and, instead, stare into a dark theater. After only a few short days in this new environment, the dancers perform in front of an audience. This environmental change can take a psychological and physical toll due to the loss of control felt by dancers due to new pressures of live performance in a new space.[16]

Psychological pressures can also come from the nature of being constantly judged on their performance along with the pressure to consistently impress. This may cause many dancers to face anxiety before or during their performances.[16] The typical anxiety experienced by dancers is categorized as state anxiety.[16] This is described as situation-specific anxiety that eventually

goes away after the intimidating situation concludes but does not typically impede the performance quality.[16,17] While some dancers have reported being able to use their anxiety as a positive influence to increase their energy and focus, others may have trouble controlling the cognitive and somatic feelings which may trigger deficits in their performance.[16] Cognitive symptoms include negative imagery and feelings while somatic symptoms may include feeling shaky, feeling unstable, having an increased heart rate, and experiencing hyperactivity. Dancing, specifically ballet, is comprised of explosive movements along with moments of precision. If a dancer does not feel grounded correctly, their balance may be inhibited, impeding their performance on stage and increasing their risk for injury.[16]

Balance

Balance is described as the ability to maintain the center of gravity over a base of support.[18] This maintenance stems from collaboration between visual, vestibular, and somatosensory/proprioceptive information.[8,19-22] Coordination between all parts of the somatosensory system provides information to the central nervous system to properly detect body alignment[21-23] and is vitally important in the execution of all functional activities, and is especially important in ballet. Good postural control has been linked to a lower risk of injury, which increases its importance.[24]

Dance incorporates postural control and balance throughout each movement and relies on accurate input from each of these three systems.[25,26] The base of support of a dancer dramatically decreases with different positions and movements such as being on relevé or being en pointe[18] making postural control more difficult to attain, so dancers must rely on proper stability, strength, and range of motion to achieve this control.[27] Although the limited base of support makes balance and postural control more difficult to maintain, dancers have been shown to

exhibit outstanding balance and proprioception that is superior to non-dancers.[11,12,18,27-36] When dancers are in classes or rehearsals, they learn techniques by mirroring the choreographer or teacher and associate the varying connections between the body and the movements[30] resulting in an enhanced awareness of their limb positioning.[28,37] Dance training results in increased neuromuscular control, coordination, sensorimotor control, and integration of movement by the nervous system.[27,28,30,37,38] With these trained qualities, dancers exhibit superior balance and proprioceptive abilities.

Contrasting literature, however, indicates that proprioception may not be automatically enhanced by dance training alone.[18,39] When comparing dancers and non-dancers ability to mimic movements, dancers only performed better when matching upper limb movements but there was no significant difference between the two groups when looking at ankle joint imitation.[28,40] Other studies have found that dancers only performed better when completing complex dance-specific activities and not when performing unchallenging tasks such as static balance.[27,38,39,41] This suggests that dance training explicitly trains the specific underlying factors needed for balance in dance but does not train proprioception or postural stability as a whole.[27,42]

Vision

When examining the sensorimotor system's contribution to dance, vision has been shown to be the dominant system in dancers.[28,39,42] This may be influenced due to how choreography is taught. Dancers spend most of their time learning technique or choreography in the studio, which is typically surrounded by mirrors. While this offers immediate feedback to correct position[43], they may learn to use visual landmarks on their body seen in the mirror to fix their posture to display better postural control rather than relying on strict proprioception. For example, dancers maintain proper vestibulocochlear equilibrium by "spotting," or gazing at one area during rotational movements.[11] Choosing an identifiable location to focus on is integral for maintaining

balance during a turn and is much easier when using a mirror. The consistent use of visual feedback during training can cause dancers to become too reliant on the mirrors and, in turn, they may require constant visual feedback to perform difficult ballet movements that require immense balance.[18,31-34,42,44] It has been found that dancers may become less dependent on this visual information with increased experience, but it still plays a vital role in all levels of dance.[30-34,44]

Others suggest dancers are less dependent on visual information, appropriately utilize all aspects of sensorimotor control, and have increased proprioception without visual landmarks when compared to non-dancers,.[27,30,37,45] This is especially important when they are on stage and must perform without visual feedback after a short rehearsal time in a new space.[31-34,44]

As mentioned previously, prior to a performance dancers must move from the studio setting to the theater. This removes the availability of visual input as mirrors are replaced with a dark theater and stage lights. This switch to a new location could be detrimental to performance if dancers are too dependent on visual cues.[18] When information is no longer equally transmitted by visual, somatosensory, and vestibular systems, the body becomes more reliant on the systems that are still availible.[20,39] For dancers, this means a shift from visual to proprioceptive systems and while some studies have supported a heightened capability in dancers to succeed in this task,[25,28,46] others have found that postural sway increases with the removal of visual feedback.[18,19,35,47-49] To specifically examine this, one study compared judo specialists and dancers during static balance exercises with eyes closed[42] and another study compared dancers performing eyes closed dynamic ballet exercises.[27] Both studies showed diminished balance in the dancers during eyes closed conditions, related to the removal of visual feedback.[27,30,42]

Measuring Balance

Previously, balance in dancers has been examined using several different tests. These previous approaches have included single leg standing versus single leg squat with or without

perturbations,[21,35,42,50-53] using an unstable surface versus a stable surface,[30] and using a plantar pressure mat or force plate to measure center of pressure and postural sway during static and dynamic activites.[27,30,35] However, many of these studies did not use dance specific activities.

A study that did examine balance using dance specific dynamic activities included pirouettes (full body rotations completed on the stabilizing leg), sutenou, glissade, and fouetté turns. Pirouettes were completed from 4th position in both en dedans and en dehors (turning towards the working leg and turning away from the working leg), pirouettes from and to 5th position, and pirouettes in arabesque or attitude. These full body movements were used to test the dancer's full ability to maintain control over the base of support throughout the entire test.[27,54]

In a study done by Gerbino et al.[55], center of pressure was compared between dancers and female soccer players using a Tekscan HR Pressure Mat. This study concluded that dancers had superior balance abilities during eyes open and eyes closed single leg stance on solid ground and foam along with weight shifts and landing from a jump.[55] The plantar pressure mat sensels, or sensory system, detects their activation and force application so the software can calculate the center of force during testing. This data was used to determine the patient's postural sway and their ability to limit this change to a variation of less than 5 sensels.[55] Other variables that can be analyzed from the HR Mat software includes anterior-posterior sway (cm), medial-lateral sway (cm), contact area (cm^2), and center of force trajectory (cm).[56-58] In a study examining reliability of the plantar pressure mats using walking gait, moderate to good reliability was determined for this assessment technique.[59]

Other well-known balance tests that were utilized all have acceptable reliability and validity included the balance error scoring system (BESS) test, the star excursion balance test (SEBT), and the modified bass test of dynamic balance (BASS).[18,28,60] The BESS test uses 3

positions (bipedal, unipedal, and tandem gait) on stable and unstable surfaces with eyes closed and hands kept at the hips. When completing this test, dancers showed fewer errors when compared with non-dancers suggesting better balance.[60,61] The SEBT is a single leg stance that measures the reach distances with the opposite leg in a clock-like fashion. Dancers exhibited further reach distances for this test, supporting enhanced balance in dancers.[18,60,62] The final test, BASS, used an alternating leg position that combines static and dynamic testing components. During this test, participants jump on a single leg between 10 positions but balance for 5 seconds at each location before continuing.[60] There was no difference found between dancers and non-dancers for this test.[60,63]

HR Mat Variables

In studies examining static balance utilizing the Tekscan HR Pressure Mat, variables assessed included sway path length(mm), range (anterior-posterior and medial-lateral sway in mm), average radial displacement(mm), average velocity overall(mm/s), average acceleration(mm/s^2), average jerk(mm/s^3), area per second(mm^2/s), circle area(mm^2), ellipse area(mm^2), ellipse angle(degree), frequency revolve(Hz), and median vibration frequency(Hz)[64], anterior-posterior and medial-lateral sway (cm)[56], peak pressures (kPa), contact area (cm^2), center of pressure oscillation area (cm^2), anterior-posterior and medio-lateral COP oscillations (cm) and velocity (cm/s)[57], and anterior-posterior and medial-lateral displacement (in).[65]

In studies examining dynamic movements and balance, variables assessed included sway path length (cm), sway velocity (cm/s), sway index(cm^2), center acquisition time(seconds)[55], time to stabilization (seconds), sway area (mm^2), anterior-posterior and medial-lateral displacement (mm), and COP path length (mm) trajectories were analyzed.[58]

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APPENDIX C

Statistical Analysis

STATISTICAL ANALYSIS

Passé en Relevé

There was one outlier in both the studio conditions. However, outliers were within 1.5 standard deviations of the mean so they were included in statistical analysis. There were no outliers for the stage condition. Data were normally distributed for studio without mirror and

stage conditions, as assessed by boxplot and Shapiro-Wilk test (p> .05), but were not normally distributed for the studio with mirror condition, as assessed by boxplot and Shapiro-Wilk test (p < .05). Sphericity was assumed, as assessed by Mauchly's test of sphericity ($p > .05$). Change in environment elicited statistically significant changes in balance time en relevé performance, $F(2,48) = 15.52$, $p < .001$, partial $\omega^2 = .39$, observed power = .99. Time in balance was 2.38 ± .804 seconds in the studio with the mirror, 2.49 ± .923 seconds in the studio without the mirror and decreased to 1.77 ± .425 seconds on stage.

Tukey post hoc testing revealed that varying environmental factors significantly impacted balance time between both studio conditions and the stage condition. Dancers performed worse in the stage condition compared to both studio conditions (Table 1). Mean differences between performance in the studio with mirror to stage was 0.61 (95% CI, .26 to .96), p< .001), and the means difference in performance between studio without mirror to stage was 0.72 (95% CI, .30 to 1.15), p< .001.

Double Pirouette

There were two outliers in the studio with mirror condition, one outliers in the studio without mirror condition and one outlier in the stage condition. However, all were included in statistical analysis. Data were not normally distributed for all conditions, as assessed by Shapiro-Wilk test ($p < .05$). Sphericity was assumed, as assessed by Mauchly's test of sphericity ($p > .05$). Change in environment elicited statistically significant changes in 95% ellipse area, $F(2,40) = 3.44$, $p = .042$, partial $\omega^2 = .15$, and observed power = .61. 95% ellipse area was 10.24 ± 6.45 cm^2 in the studio with the mirror, 8.78 ± 6.20 cm^2 in the studio without the mirror and increased to 12.64 ± 8.42 cm^2 on stage.

Tukey post hoc analysis revealed that varying environmental factors significantly impacted ellipse area between studio without mirror to stage. Dancers performed better in the

studio without mirror condition as compared to the stage condition (Table 1). Mean differences between studio without mirror to stage was 3.86 (95% CI .78 to 8.49), p = .12.

Fouetté

There was one outlier found for the stage condition. However, the outlier was within 1.5 standard deviations from the mean so it was included in data analysis. The data were normally distributed for the studio conditions, as assessed by boxplot and Shapiro-Wilk test (p> .05). Data were not normally distributed for the stage condition, as assessed by Shapiro-Wilk test ($p < .05$). Sphericity was assumed, as assessed by Mauchly's test of sphericity ($p > .05$). Change in environment elicited statistically significant changes in fouette performance, F(2,48) = 4.29, p= .02, partial ω^2= .15, observed power = .72. Number of fouette's performed was 7.49 ± 2.23 rotations in the studio with the mirror and decreased to 6.72 ± 2.50 rotations in the studio without the mirror and to 6.07 ± 2.73 rotations on stage.

Tukey post hoc testing revealed that varying environmental factors significantly impacted fouetté rotations. Dancers completed significantly fewer fouetté rotations in the stage condition compared to the studio with the mirror (Table 1). Mean differences between studio with mirror to stage was 1.43 (95% CI, .10 to 2.75), p=.032.

APPENDIX D

IRB Documents and Study Procedures Form

INDIANA UNIVERSITY INFORMED CONSENT STATEMENT FOR

Effects of Varied Turnout and Environmental Conditions on Balance Measures in Collegiate Ballet Dancers

You are invited to participate in a research study using a force plate and pressure mat to determine the effects of various conditions encountered in typical ballet practice on dancers' balance. You were selected as a possible participant because you are currently enrolled as a ballet major at Indiana University and are 18-25 years of age. Please read this form and ask any questions you may have before agreeing to participate in the study.

This study is being conducted by Carrie Docherty, PhD, ATC; Alyssa McPherson MS, ATC; Marissa Ramos, BS, ATC; and Kelley Wiese BS, ATC in the Department of Kinesiology at Indiana University Bloomington.

STUDY PURPOSE

Balance is the foundation of all ballet movements and can be affected by a variety of outside causes, such as performance space and the amount of turnout each dancer uses. The fist purpose of this study is to determine how utilizing a higher degree of turnout affects a dancer's balance. The second purpose is to determine how a dancer's balance is affected by the varied lighting and space conditions encountered in typical training and performance.

NUMBER OF PEOPLE TAKING PART IN THE STUDY

If you agree to participate, you will be one of up to 80 dancers who will be participating in this research. We will be recruiting current ballet majors from Indiana University.

PROCEDURES FOR THE STUDY

If you agree to participate in this study, you will be participating in 3 testing sessions that will occur over 3 days. At the beginning of the first testing session, you will receive a questionnaire to determine if you qualify to participate in the study.

If you qualify for the study and decide to participate, you will begin by answering a brief questionnaire about your dance history and some other general characteristics. Following the questionnaire, we will measure your normal turnout standing on a studio floor. Then, we will measure your turnout utilizing a pair of rotational turnout discs. During this process, you will be able to use a ballet barre for balance as needed.
Next, you will balance on a force plate device in 3 different ballet positions (first position, passé, and arabesque), each in 4 different degrees of turnout (130°, 150°, natural, and "forced" – as determined by your standing turnout measurement.) You will complete 3 trials of each condition.

For the second part of this study, we will test your balance on a plantar pressure mat in 4 different positions (first position en releve, passé en releve, pirouette en dehors, and fouetté en dehors) in 3 different environmental conditions (typical studio space, studio space but facing away from the mirrors, and typical stage space with stage lighting.) You will also be asked to complete as many revolutions of a pirouette and of a fouetté turn as you feel comfortably capable of in each setting. These last two turns will take place on typical performance flooring without the pressure mat. You will complete 3 trials of each condition. This second portion of the study will take place across two different days: one day will take place in the studio as we test the two studio conditions, and the other day will take place in the stage space as we test the stage condition.

RISKS OF TAKING PART IN THE STUDY

While participating in the study the risks are:
While performing the balance tests on both the force plate and pressure mat, there is a risk of losing balance and/or falling. Falling during testing could possibly result in an injury or injuries to the lower extremity, torso, upper extremity and/or head. If an injury occurs during testing, researchers will provide immediate care and suggest a proper referral source if needed. Subjects will not be asked to complete tasks they feel uncomfortable with attempting.

BENEFITS OF TAKING PART IN THE STUDY

You are not expected to directly benefit from this research. However, as a result of this study, we will gain more knowledge about how ballet dancers train and prepare for performances. Overall, this study could change how dancers train and have an impact on reducing the amount of overall injuries suffered. These changes could also potentially increase overall performance.

CONFIDENTIALITY

Efforts will be made to keep your personal information confidential. We cannot guarantee absolute confidentiality. Your personal information may be disclosed if required by law. Your identity will not be revealed in any reports or publications, and all electronic data will be stored in a secure, Indiana University online server. Physical data collection sheets will be stored in a locked file cabinet in a locked room.

Organizations that may inspect and/or copy your research records for quality assurance and data analysis include groups such as the study investigator and his/her research associates, the Indiana University Institutional Review Board or its designees, and (as allowed by law) state or federal agencies, specifically the Office for Human Research Protections (OHRP) who may need to access your research records.

WILL MY INFORMATION BE USED FOR RESEARCH IN THE FUTURE?

Information collected from you for this research may be used for future research studies or shared with other researchers for future research. If this happens, information which could identify you will be removed before any information or specimens are shared. Since identifying information will be removed, we cannot ask for your additional consent.

COMPENSATION FOR INJURY

In the event of physical injury resulting from your participation in this research, medical referral options will be given to you. Any costs not covered by your health care insurer will be your responsibility. It is your responsibility to determine the extent of your health care coverage. If you are participating in research which is not conducted at a medical facility, you will be responsible for seeking medical care and for the expenses associated with any care received.

CONTACTS FOR QUESTIONS OR PROBLEMS

For questions about the study or a research-related injury, contact Dr. Carrie Docherty at 812-856-6035. If you cannot reach the researcher during regular business hours (i.e., 8 a.m. to 5 p.m.) please call the IU Human Subjects Office at 812-856-4242 or 800-696-2949.

For questions about your rights as a research participant, to discuss problems, complaints, or concerns about a research study, or to obtain information or offer input, contact the IU Human Subjects Office at 812-856-4242 or 800-696-2949.

VOLUNTARY NATURE OF THIS STUDY

Taking part in this study is voluntary. You may choose not to take part or may leave the study at any time. Leaving the study will not result in any penalty. Your decision whether or not to participate in this study will not affect your current or future relations with Indiana University.

SUBJECT'S CONSENT

In consideration of all of the above, I give my consent to participate in this research study.

I will be given a copy of this informed consent document to keep for my records. I agree to take part in this study.

Subject's Printed Name:_____

Subject's Signature:_____ **Date:** _____

(must be dated by the subject)

Printed Name of Person Obtaining Consent:_____

Signature of Person Obtaining Consent: _____**Date:**_____

STUDY PROCEDURES CHECKLIST

Before subject arrives:

1. Remove HR Mat Sensor and Floor Display from box
2. Place sensor on a hard floor surface
3. Open black Tekscan case
4. Lift VersaTek cuff housing cover attached with Velcro
5. Connect VersaTek Cuffs to Connectors (green)
6. Connect the grounding wire to both VersaTek Sensor Cuffs
7. Connect Cuff Cables from Cuffs to the Hub. Left Cuff should be connected to Channel 1 on the Hub and the Right Cuff should be connected to Channel 2.
8. Connect the USB cable to the USB port on the Hub. Connect other end to USB port on laptop.
9. Plug AC adapter into a wall outlet. Connect AC adapter into the hub unit.
10. The green power LED light on the hub and green CH1 and CH2 port LEDs should all illuminate.
11. Start HR Mat Research v. 6.60
12. Measure a 3 by 3 ft. square and mark the area on the floor with 1 inch gaffer tape

After subject arrives:

1. Patient signs Informed Consent form and completes health history and demographics questionnaire
2. Take height and weight
3. Adjust weight in lb to weight in newtons
4. Patient completes self-prescribed warm up (10 minutes)
5. Click "New Patient" to open a new patient record, enter the subject's information, click OK.
6. Click "New Recording" (blank white paper icon)
7. Calibration
    - Options → set legend → raw pressure → upper value should be set at 250 N
    - Tools → Calibration → Calibrate → Step → Enter subject's weight → Start
        - Once prompted, subject will step onto mat and balance as still as possible
        - Hit OK to apply
        - Hit Save Cal. File as "Calibration"
        - Hit OK → Exit
8. Data Acquisition Parameters
    - Options → Acquisition Parameters
        - Recording time: 5 seconds
9. Testing: (*Testing location and order of functional movements tested will be randomized for each participant using counterbalance sheet*)
    - Passé en relevé balance: "When I instruct you to, step forward onto the mat and take your natural first position. When I say go, you will plie then relevé on your preferred stabilization leg and passé with the other leg and balance until I say stop. You should balance and spot how you normally would during a standard ballet performance with your arms in first position. At the end of the trial, you may step off the mat. You will complete this three times. Do you have any questions? Can you show me what that looks like? You may now take your first position. Ready? Go... Take your first position again, go... Take your first position again, go... Take your first position again, go."
        - Record button

        - The recording is set to begin immediately and measure for 5 seconds before shutting off
    - Fill out patient's data collection forms based on performance
    - Save settings studio **with** mirror:
        - File, Save Movie As, MR1, Yes, subject's number should be selected, Save.
            - Trial 1 = *ID#_MR1*
            - Trial 2 = *ID#_MR2*
            - Trial 3 = *ID#_MR3*
    - Save settings studio **without** mirror:
        - File, Save Movie As, R1, Yes, subject's number should be selected, Save.
            - Trial 1 = *ID#_R1*
            - Trial 2 = *ID#_R2*
            - Trial 3 = *ID#_R3*
    - Save settings stage:
        - File, Save Movie As, SR1, Yes, subject's number should be selected, Save.
            - Trial 1 = *ID#_SR1*
            - Trial 2 = *ID#_SR2*
            - Trial 3 = *ID#_SR3*
- Pirouette: "When I instruct you to, step forward onto the mat and take your fourth position in preparation for a double pirouette en dehors to your preferred turning side. When I say go, you will complete the double pirouette and land in a fourth position as you normally would during a standard ballet performance, using proper spotting and moving arms through third to first to third position. At the end of the trial, you may step off the mat. You will complete three test trials. Do you have any questions? Can you show me what that looks like? You may now take your fourth position. Ready? Go... Take your fourth position again, go... Take your fourth position again, go."
    - Record button
        - The recording is set to begin immediately and measure for 5 seconds before shutting off
    - Fill out patient's data collection forms based on performance
    - Save settings studio **with** mirror:
        - File, Save Movie As, MP1, Yes, subject's number should be selected, Save.
            - Trial 1 = *ID#_MP1*
            - Trial 2 = *ID#_MP2*
            - Trial 3 = *ID#_MP3*
    - Save settings studio **without** mirror:
        - File, Save Movie As, P1, Yes, subject's number should be selected, Save.
            - Trial 1 = *ID#_P1*
            - Trial 2 = *ID#_P2*
            - Trial 3 = *ID#_P3*
    - Save settings stage:

- File, Save Movie As, SP1, Yes, subject's number should be selected, Save.
    - Trial 1 = *ID#_SP1*
    - Trial 2 = *ID#_SP2*
    - Trial 3 = *ID#_SP3*

- Maximum Fouetté Rotations: "You will now complete your maximum number of fouetté turns en dehors on the studio flooring. You may begin with a single pirouette and follow with as many fouetté turns as you can. You must begin and land in fourth position, spot, and move arms from third to first to second during the fouetté and finish with arms in third position as you normally would during a standard ballet performance. You will complete this three times. Do you have any questions? Can you show me what that looks like? Ready? Take your fourth position again, go... take your fourth position again, go."
    - Fill out patient's data collection forms based on performance

10. Complete the same steps as #8 for each condition
11. Stage Testing Day
    - Complete steps 1-11 of the "before subject arrives" section
    - Tape Marley square on floor and mark a 3X3 foot area with 1 inch gaffer tape
    - Discuss with technical crew to ensure stage lights are on
        - 2 lights per side on booms for low side light (knows as kickers or shins)
        - Front light systems: 45 degree angle and 75 degree angle
        - Spotting light
    - Complete testing facing downstage
12. Post-Testing
    - Have patient complete the exit survey questionnaire

APPENDIX E

Data Collection Form and Questionnaire

Subject ID #:_____

Study #1804916974

ENTRANCE QUESTIONNAIRE *(Initial)*

ELIGIBILITY QUESTIONNAIRE:

1. Are you between the ages of 18-25 years old? Yes No
2. Are you currently enrolled at Indiana University as a Ballet major? Yes No
3. Do you have any current lower extremity injuries for the following?
   a. Ankle Yes No
      i. Does this currently limit your ballet participation? Yes No
      ii. If yes, please explain:

      _____

      _____

   b. Knee Yes No
      i. Does this currently limit your ballet participation? Yes No
      ii. If yes, please explain:

      _____

      _____

   c. Hip Yes No
      i. Does this currently limit your ballet participation? Yes No
      ii. If yes, please explain:

      _____

      _____

4. Have you had any surgery on your lower extremity within the last 6 months? Yes No
   a. If yes, please explain:

   _____

5. Do you have any vestibulocochlear dysfunctions (i.e. vertigo, current migraine)? Yes No

Age: _____ years old **Year (circle):** Fresh Soph Jr Sr

1. Do you currently participate in at least 5 days of technique classes/rehearsals per week?

   Yes No

2. Have you ever had any lower extremity surgery? Yes No

   If yes, please explain – including dates as possible:

   _____

   _____

3. Have you been sick recently? Yes No

   If yes, please explain:

   _____

   _____

4. Do you have any other medical conditions? Yes No

   If yes, please explain:

   _____

   _____

5. Approximately how many hours *on average* do you dance per week?

   _____hours

6. How many years *(approximately)* have you been dancing in total, all forms?

   _____ years

7. How many years of formal ballet training have you had? _____ years

8. What types of dance have you participated in?

_____

_____

9. How much dance training did you receive over the past summer?

_____

_____

10. What is your preferred balance/supporting leg? Right Left

11. What is your preferred turning side? Right Left

Any Other Comments/Concerns?

_____

_____

_____

_____

Subject ID #:_____

Study #1804916974

ENTRANCE QUESTIONNAIRE *(Testing Day A)*

1. How many hours have you danced today? _____ hours
    a. If yes, in what shoes?

    _____

    b. If yes, how long since you danced?

    _____

2. What other physical activity have you participated in today?

    _____

3. Have you done anything differently today from the other days of testing regarding nutrition, hydration, sleep or caffeine intake that may not allow you to complete these tests at the best of your ability?
    a. If yes, please explain why:

    _____

    _____

    _____

4. Have you suffered any different emotional or physical stresses today from the other days of testing that may not allow you to complete these tests at the best of your ability?
    a. If yes, please explain why:

    _____

    _____

    _____

EXIT QUESTIONNAIRE *(Testing Day A)*

1. Do you feel you completed each test to the best of your ability today? Yes No
    a. If no, please explain why:

    _____

    _____

For the balance exercises completed today

FACING THE MIRROR….

2. …please rate how you perceived your **<u>performance</u>** on the following tests, with 5 being the best and 1 being the worst:
    a. Passé en relevé balance: 1 2 3 4 5
    b. Pirouette
        i. Double pirouette on mat: 1 2 3 4 5
    c. Fouetté
        i. Max rotations on studio flooring: 1 2 3 4 5

3. …please rate how **<u>balanced</u>** you felt during the following tests, with 5 being the best and 1 being the worst:
    a. Passé en relevé balance: 1 2 3 4 5
    b. Pirouette
        i. Double pirouette on mat: 1 2 3 4 5
    c. Fouetté
        i. Max rotations on studio flooring: 1 2 3 4 5

4. …please rate how **<u>difficult it was to spot</u>** during the following tests, with 5 being the easiest and 1 being the hardest:
    a. Passé en relevé balance: 1 2 3 4 5
    b. Pirouette
        i. Double pirouette on mat: 1 2 3 4 5
    c. Fouetté
        i. Max rotations on studio flooring: 1 2 3 4 5

Subject ID #:_____

Study #1804916974

ENTRANCE QUESTIONNAIRE *(Testing Day B)*

5. How many hours have you danced today? _____ hours
    a. If yes, in what shoes?

    _____

    b. If yes, how long since you danced?

    _____

6. What other physical activity have you participated in today?

    _____

7. Have you done anything differently today from the other days of testing regarding nutrition, hydration, sleep or caffeine intake that may not allow you to complete these tests at the best of your ability?
    a. If yes, please explain why:

    _____

    _____

    _____

8. Have you suffered any different emotional or physical stresses today from the other days of testing that may not allow you to complete these tests at the best of your ability?
    a. If yes, please explain why:

    _____

    _____

    _____

EXIT QUESTIONNAIRE *(Testing Day B)*

5. Do you feel you completed each test to the best of your ability today? Yes No
    a. If no, please explain why:

    _____

    _____

For the balance exercises completed today
********WITHOUT* THE MIRROR***….

6. …please rate how you perceived your **performance** on the following tests, with 5 being the best and 1 being the worst:
    a. Passé en relevé balance: 1 2 3 4 5
    b. Pirouette
        i. Double pirouette on mat: 1 2 3 4 5
    b. Fouetté
        i. Max rotations on studio flooring: 1 2 3 4 5

7. …please rate how **balanced** you felt during the following tests, with 5 being the best and 1 being the worst:
    a. Passé en relevé balance: 1 2 3 4 5
    b. Pirouette
        i. Double pirouette on mat: 1 2 3 4 5
    b. Fouetté
        i. Max rotations on studio flooring: 1 2 3 4 5

8. …please rate how **difficult it was to spot** during the following tests, with 5 being the easiest and 1 being the hardest:
    a. Passé en relevé balance: 1 2 3 4 5
    b. Pirouette
        i. Double pirouette on mat: 1 2 3 4 5
    c. Fouetté
        i. Max rotations on studio flooring: 1 2 3 4 5

Subject ID #:_____

Study #1804916974

ENTRANCE QUESTIONNAIRE *(Testing Day C)*

1. How many hours have you danced today? _____ hours
    a. If yes, in what shoes?

    _____

    b. If yes, how long since you danced?

    _____

2. What other physical activity have you participated in today?

    _____

3. Have you done anything differently today from the other days of testing regarding nutrition, hydration, sleep or caffeine intake that may not allow you to complete these tests at the best of your ability?
    a. If yes, please explain why:

    _____

    _____

    _____

4. Have you suffered any different emotional or physical stresses today from the other days of testing that may not allow you to complete these tests at the best of your ability?
    a. If yes, please explain why:

    _____

    _____

    _____

EXIT QUESTIONNAIRE (Testing Day C)

1. Do you feel you completed each test to the best of your ability today? Yes No
    a. If no, please explain why:

    _____

    _____

For the balance exercises completed today ***IN THE STAGE SPACE ***….

2. …please rate how you perceived your **performance** on the following tests, with 5 being the best and 1 being the worst:
    a. Passé en relevé balance: 1 2 3 4 5
    b. Pirouette
        i. Double pirouette on mat: 1 2 3 4 5
    c. Fouetté
        i. Max rotations on studio flooring: 1 2 3 4 5

3. …please rate how **balanced** you felt during the following tests, with 5 being the best and 1 being the worst:
    a. Passé en relevé balance: 1 2 3 4 5
    b. Pirouette
        i. Double pirouette on mat: 1 2 3 4 5
    c. Fouetté
        i. Max rotations on studio flooring: 1 2 3 4 5

4. ….please rate how **difficult it was to spot** during the following tests, with 5 being the easiest and 1 being the hardest:
    a. Passé en relevé balance: 1 2 3 4 5
    b. Pirouette
        i. Double pirouette on mat: 1 2 3 4 5
    c. Fouetté
        i. Max rotations on studio flooring: 1 2 3 4 5

APPENDIX F

Power Analysis

POWER ANALYSIS

Fronczek–Wojciechowska M, Padula G, Kowalska J, Galli M, Livatino S, Kopacz K. Static balance and dynamic balance related to rotational movement in ballet dance students. *Int J Perf Anal Sport.* 2016;16(3):801-816.

Parameters assuming 0.8 power

- Force Plate
    - Max Radius (how far they swayed from the center point in all directions)
        - Eyes closed – eyes open (dancers in static, bipedal position)
          SD
        - 27.7 – 16.8 = 10.9 = .7 = 26 Subjects
          (25.4 + 5.7)/2 = 15.5

    - Transversal Range (how far they swayed medially and laterally from the center point)
        - Eyes closed – eyes open (dancers in static, bipedal position)
          SD
        - 32.1 – 17.5 = 14.6 = .8 = 20 Subjects
          (34.5 + 3.8)/2 = 19.1

Gerbino PG, Griffin ED, Zurakowski D. Comparison of standing balance between female collegiate dancers and soccer players. *Gait Posture.* 2007;26(4):501-507.

Parameters assuming 0.8 power

- Plantar Pressure Mat
    - Center of Pressure
        - Soccer players with eyes open – dancers with eyes open
          SD
        - 1.9-1.3 = .6 = 35 subjects
          1

Subject Size: 20 + 26 + 35 = 27 Subjects
3

Kelley Rock Wiese

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EDUCATION & HONORS

Indiana University – Bloomington, IN 2017-2019
Master of Science, Kinesiology/Athletic Training Anticipated Graduation May 3, 2019
- GPA: 4.0
- Thesis: *Functional balance measures in ballet dancers with varying visual input*

James Madison University – Harrisonburg, VA 2013-2017
Bachelor of Science, Athletic Training
- Graduation Honors: Summa Cum Laude
- Cumulative GPA: 3.9
- President's List Fall 2015, 2016; Spring 2014, 2016, 2017
- Dean's List Fall 2013, 2014; Spring 2015
- Golden Key National Honor's Society

PROFESSIONAL EXPERIENCE

Indiana University Ballet Theater 2017- 2019
Head Athletic Trainer/Graduate Assistant
- Responsible for providing coverage to Indiana University Ballet dancers during all ballet classes, rehearsals, and performances including *The Nutcracker*, *Fall Ballet*, *Spring Ballet*, and *Student Choreographic*
- Clinical Preceptor

Indiana University Marching Hundred 2018
- Provided Athletic Training coverage for the marching band during an IU Football game

Raas Royalty Indian Dance Competition 2018
- Provided Athletic Training coverage for the Raas Royalty Indiana Dance Competition at Indiana University

Owen Valley High School 2017
- Graduate Assistant Athletic Trainer for pre-season football coverage

PROFESSIONAL CERTIFICATIONS AND LICENSES

- Board of Certification (BOC) #2000027563 2017-Present
- Indiana Licensed Athletic Trainer #36002890A 2017-Present
- National Provider Identifier #1427584127 2017-Present
- American Red Cross CPR/AED for the Professional Rescuer 2016-Present
- American Red Cross First Aid 2016-Present
- M1 Graston Technique Trained 2017-Present
- Safe Sports Certified 2017-Present

UNIVERSITY TEACHING EXPERIENCE

Indiana University Associate Instructor 2019
- K205: Structural Kinesiology Lab

Indiana University Teaching Assistant 2017
- A488: Advanced Techniques in Athletic Training

Indiana University Ballet Theater Lectures
- Turnout for Ballet Dancers 2018
- Stretching for Ballet Dancers 2018
- Accessing Healthcare 2018
- Teaching Proper Body Mechanics 2019

PRE-PROFESSIONAL EXERIENCE

James Madison University
- Senior Lead Athletic Training Student: Cheerleading 2017
- Junior Athletic Training Student: Baseball 2016

Harrisonburg High School 2016
- Senior Lead Athletic Training Student
- Football, Sideline and Competition Cheer, Women's Volleyball, Gymnastics, Men's and Women's Basketball, Track and Field, Cross Country

Eastern Mennonite University 2015
- Men's and Women's Soccer, Women's Volleyball, Field Hockey, Track/Cross Country, Men's and Women's Basketball

General Medicine Clinic Observation 2016 –2017
- Performed initial assessment of patient conditions and presented case and possible solutions to physician

James Madison University Health Center Clinical Observation 2015

AWARDS

Indiana University – Bloomington, IN 2019
John W. Schrader Educational Service Award
- Awarded annually to the graduate student who exemplifies the qualities, contributions and services toward Athletic Training Education

Indiana University – Bloomington, IN 2018
Schrader Family Fellowship
- Awarded annually to the Indiana University graduate athletic training student that has made a positive impact on the athletic training program and their fellow students

James Madison University – Harrisonburg, VA 2017
Sports Medicine Director Award
- Awarded annually to the undergraduate athletic training student that demonstrates strong leadership skills, personifies the highest level of professionalism, and exemplifies the potential to make future contributions to the profession of athletic training

ADDITIONAL WORK EXPERIENCE

James Madison University Recreation Center Group Fitness Instructor 2016 –2017
- Cardio Dance, Barre, Core
- Injury Prevention Class 2017
  - 8-week course instructing participants on proper mechanics and strength to prevent injury

Actor's NET of Bucks County Choreographer 2012- 2017
- Choreographer for 4 week performing arts program for 7-17 year old participants

Broadway NYC, NY 2006- 2007
- Cast member of "How The Grinch Stole Christmas"

Lilly Pulitzer 2012- 2016
- Retail Sales Associate

ACTIVITES

International Association for Dance Medicine and Science 2019
- Accepted presentation for October 2019 annual conference
- Interactive workshop: *Making foot intrinsic work functional*

School of Public Health Research Day – Bloomington, IN 2019
- Poster Presentation: *Functional balance measures in ballet dancers with varying visual input*

Virginia Athletic Trainer's Association Conference 2016, 2017
- James Madison University Quiz Bowl Team Member
- 2017 Case Presentation: *Type II Long QT Syndrome in a Collegiate Baseball Athlete with Secondary Complications.* Williamsburg, VA, 2017.

Madison Athletic Training Student Association 2013- 2017

Vice President of Outreach 2016- 2017
- Organized community service opportunities
- Creating clothing orders to market the profession

Alpha Phi International Fraternity

Vice President of Chapter Operations 2015- 2015
- Organized chapter events emphasizing community service and growth of the organization

Ireland Study Abroad 2016
- Studied and compared the foundation of sports medicine overseas
- Examined dry needling procedures
- Completed evaluations of biomechanics to identify deficits and created programs to strengthen problem areas

DIGITAL EXPERTISE

SPSS (Statistical Package for the Social Sciences)
- Software used to edit and analyze data

Sportsware
- Injury Tracking Software

Microsoft Office Suite
- Microsoft Word, Microsoft Powerpoint, Microsoft Excel, Microsoft Outlook

PROFESSIONAL MEMBERSHIPS

- National Athletic Trainers' Association 2015-Present
- Mid-Atlantic Athletic Trainers' Association 2015-2017
- Virginia Athletic Trainers' Association 2015-2017
- Indiana Athletic Trainers' Association 2018-Present
- Great Lakes Athletic Trainers' Association 2018-Present
- International Association for Dance Medicine and Science 2019-Present